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OVERVIEW OF DoD REQUIREMENTS AND CAPABILITIES FOR NATURAL ENVIRONMENTAL EFFECTS IN MILITARY MODELS AND SIMULATIONS

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1. INTRODUCTION

The Defense Modeling and Simulation Office (DMSO) sponsored surveys to be taken to establish the DoD requirements and capabilities for the natural environment and environmental effects in military models and simulations. The survey was conducted as a task within the DMSO Project, Environmental Effects for Distributed Interactive Simulation, E^{2}DIS (Heckathorn, 1994). A tri-service survey team was established and the Science Technology Corporation (STC) was selected to conduct a survey of DoD requirements for environmental effects in military M&S and a second survey to catalog the current and eminent models and data bases relevant to satisfying those requirements. STC also conducted an analysis of the shortfalls between stated requirements and current capabilities. This paper describes the results of the surveys and the analyses of needed new capabilities.

2. REQUIREMENTS AND CAPABILITIES SURVEY QUESTIONNAIRES

Because the results of both the requirements and capabilities surveys would be compared and assessed, the two questionnaires were structured as similarly as possible. Both questionnaires were divided into two parts: administrative information and technical information.

The administrative information section requested information on the simulation or model title, a brief general description, the Service office of responsibility and a technical expert for the simulation or model.

The technical information section of the questionnaires is the essence of the surveys. It has seven subsections and three attachments. The seven subsections were:

-- Critical Environmental Factors
-- Status of the Simulation, Model or Database
-- Application of the Simulation, Model or Database
-- Simulation or Model's Spatial and Temporal Domain
-- Current Requirements
-- Future Requirements
-- E2DIS and/or Environmental Capabilities Briefing

Attachment 1 requested information for atmospheric data and effects (surface to 300 km altitude) for each simulation or model:

-- Atmospheric Data Type
-- Fidelity Requirements
-- Sensor, Communications and Weapon System Description(s)

Attachment 2 requested similar information for near space (300 km to 70,000 km) data and effects. (Only the atmospheric applications were briefed at the BAC.) Attachment 3 addressed other requirements, such as, scalability of the simulation domain, computer software and hardware issues, security, VV&A, data currency (i.e., model, real-world or real-time data)

The requirements and capabilities survey questionnaires are provided in the respective, complementary documents (Piwowar et al., 1996 and Burgeson et al., 1996a).

3. RESULTS OF THE REQUIREMENTS SURVEY

The Requirements Survey was initiated as a "top-down" project, that is, to initiate the survey from the highest office in each Service that had direct responsibility for modeling and simulation. As Figure 1 shows, 170 service organizations were polled and 208 major M&S efforts were identified. The 208 major efforts are listed in Piwowar et al., 1996. The Army identified 107 M&S efforts which is more than the other Services combined. Of the 208 major programs, 74 were thoroughly documented through the survey questionnaire process.

The models and simulations were categorized by DMSO functional area and hierarchical level. The functional areas are: Research and Development; Test and Evaluation; Analysis; Production and Logistics; and, Military operations, Education and Training. Hierarchical levels of simulations or models are: Campaign; Mission; Many-0n-Many or Few-on-Few; One-on-One; and, Engineering Level. Figure 2 shows the functional area versus hierarchical level distribution of the 74 survey models /simulations. With the exception of the production and logistics category, there is a fairly even distribution across these areas/levels. Because of this even distribution across functional areas and hierarchical levels, the sample size of 74 well-documented questionnaires was considered to be sufficient to draw broad conclusions to benchmark current status and to develop new requirements and plans.

Also shown in Figure 2 are those models/simulations that were identified by the returned questionnaires as having critical environmental factors. These are displayed in parenthesis in the lower right of each cell. It is noteworthy that only 55% (5 of 9) of the Campaign-level M&S, only 60% of the Military Operations M&S, and only 68% of the Analysis M&S were identified as having critical environmental factors. These statistics are somewhat perplexing since these are the models and simulations that warfighters, who are the ultimate customers for M&S efforts and who are reasonably familiar with real-world environmental factors, would be expected to use routinely.

Sixty percent of the models and simulations were operational at the time the requirements survey was taken and ninety percent were expected to be operational by FY97. Figure 3 shows the number of models/simulations identified by military object families (i.e., forces, platforms, weapon systems, communication systems and sensors) and the number that identified atmospheric effects by family type. The lack of atmospheric effects in so many of these families indicate the environmental support groups, perhaps through the DMSO Executive Agent for Air and Space, need to work more closely with these modelers/simulators to bring to their recognition the potential atmospheric impacts and the current capabilities that are available.

Figure 4 shows the distribution of simulation types surveyed: live, virtual and constructive. Virtual simulations have by far the greatest usage. Distributed Interactive Simulations (DIS) were reported to be used currently by 19 % of the models/simulations. By FY97 this number was projected to grow to 57%. Thirty six percent of the responses that had no plan to be involved with DIS.

The requirements survey listed 26 atmospheric data types and 23 near-space environment data types for the respondents to select as requirements for their models/simulation. (Only the atmospheric applications were briefed at the BAC.) Respondents were requested to indicate the current usage and the potential for future usage of the data types. The results are shown in Figure 5. Those most commonly identified parameters were wind, precipitation, clouds, aerosols, fog, temperature and visibility. Each parameter was identified in 60% or more of the model/simulation requirements.

The spatial and temporal domains of atmospheric data requirements are shown in Figures 6 through 8. It is interesting to note that for most atmospheric data types, the requirements for spatial and temporal resolution spans 7 or more orders of magnitude.

Other topics that are addressed in the requirements survey results are model scalability, computer operating systems, host computer hardware, programming language, database management systems, transportability, data media, security and VV&A.

4. RESULTS OF THE CAPABILITIES SURVEY

Figure 9 shows that 41 service organizations were polled and 156 major M&S models or databases were identified. The 156 major efforts are listed in Burgeson et al., 1996a. The Air Force and Navy, respectively, identified 65 and 60 M&S efforts. Of the 156 major models or databases, 152 were thoroughly documented through the capabilities survey questionnaire process.

Figure 10 shows the functional area versus hierarchical level distribution of the 152 environmental databases and models. The data in this figure indicate that there are three dominant functional areas for the databases and models surveyed: Research and Development, Analysis, and Military Operations. Only one model supported Campaign-level models and simulations.

Figure 11 shows that the environmental capabilities database was comprised of 26 environmental databases, 57 environmental models, and 59 environmental effects models.

Figure 12 depicts the number of capabilities that provide each atmospheric data type. Note that transmissivity and clouds dominate the list of current capabilities, being provided by 25 and 26 models or databases, respectively. Temperature, wind and radiative features account for secondary peaks.

An appendix in Burgeson et al., 1996a presents a brief description of each model and database, along with the technical point of contact and critical environmental factors.

5. ANALYSIS OF REQUIREMENTS VERSUS CAPABILITIES

This section discusses the comparison between the environmental fidelity requirements identified from the 74 DoD simulation models in the Requirements Survey and the 152 environmental model and database capabilities in the Capabilities Survey. Burgeson, et al., 1996b compares fidelity requirements and capabilities for the eight atmospheric data types identified as those needed the most in the Requirements Survey. Those atmospheric data types are: aerosols, clouds, fog, humidity, precipitation, temperature, visibility and wind. The analysis compares the surveyed environmental fidelity requirements with capabilities in terms of their horizontal, vertical and temporal scales. The comparative analysis identifies deficiencies of current environmental simulation tools and environmental databases, and points out critically needed new environmental models, codes, and databases.

As an example analysis, the following shows the fidelity requirements and capabilities for cloud data. Comparisons are depicted in bargraphs that display the fidelity requirements and capabilities in the horizontal, vertical and temporal scales (Figures 13, 14 and 15 respectively). Each white vertical bar represents a unique environmental M&S requirement whose fidelity has been specified; each black vertical bar represents a unique environmental capability at its available fidelity. The requirements and capabilities are arranged along the horizontal axis in order of decreasing fidelity from left to right, an ordering that readily shows the match between requirements and capabilities. Figure 13 shows that there were 5 simulation models that required horizontal fidelity of cloud data at 100 meters or less and that there is one environmental model that can provide 100 meter fidelity.

A primary purpose of the E^2DIS Survey Task was to assess current capabilities for specifying the atmospheric environment for modeling and simulation at the fidelity needed by the military services M&S communities. The assessment was made by: (1) comparing the spatial and temporal environmental fidelity requirements and capabilities; (2) identifying the extent of defined deficiencies; and, (3) recommending the development of new models and/or databases with suggested fidelity capabilities.

Figure 16 shows the resulting deficiencies determined from these analyses. A deficiency (d) was defined as a condition in which 25 percent or more of the total requirements cannot be

matched by current capabilities. A major deficiency (D) was defined when more than 50 percent of the total fidelity requirements cannot be matched. Note that in Figure 16, all horizontal fidelity capabilities are deficient (eight of eight) and that half are major deficiencies. Additionally, more than half the vertical capabilities are deficient.

Analogous to the requirements report, the capabilities report also addresses model scalability, computer operating systems, host computer hardware, programming language, database management systems, transportability, data media, security and VV&A.

6. DATABASE AVAILABILITY

The complete database for the Requirements and Capabilities Surveys are available in the form of tables, queries and reports in *PARADOX for Windows*-Version 5.0. It can be obtained through the first author of this report.

7. ACKNOWLEDGMENTS

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REFERENCES

Burgeson J.C., T.M. Piwowar, P.D. Try, D.D. Grantham, S. Brand, A.E. Wetmore, 1996a: *Natural Environmental Effects in Military Models and Simulations: Part II - A Survey of Capabilities*. Technical Report No. PL-TR-96-2040, U.S. Air Force Phillips Laboratory, Hanscom Air Force Base, Massachusetts.

Burgeson J.C., T.M. Piwowar, P.D. Try, D.D. Grantham, S. Brand, A.E. Wetmore, 1996b: *Natural Environmental Effects in Military Models and Simulations: Part III - An Analysis of Requirements Versus Capabilities*. Technical Report No. PL-TR-96-2039, U.S. Air Force Phillips Laboratory, Hanscom Air Force Base, Massachusetts.

Heckathorn, H., 1994: Environmental Effects for Distributed Interactive Simulation (E^2DIS). *Proceedings, 1994 Meeting of the IRIS Specialty Group on Targets, Backgrounds and Discrimination*, Infrared Imagery Society, Monterey California, February 1994.

Piwowar, T.M., J.C. Burgeson, P.D. Try, D.D. Grantham, S. Brand, A.E. Wetmore, 1996: *Natural Environmental Effects in Military Models and Simulations: Part I - A Survey of Requirements*. Technical Report No. PL-TR-96-2029, U.S. Air Force Phillips Laboratory, Hanscom Air Force Base, Massachusetts.

Service / Agency	Requirements Survey Results			
	No. of Organizations Polled	No. of Organizations Responding	No. of Major M&S Efforts	No. of Questionnaires Completed
Army	98	40	107	17
Navy	28	16	51	28
Marine Corps	5	5	8	5
Air Force	37	17	39	21
ARPA	2	1	1	1
Coast Guard	0	1	2	2
Totals	170	80	208	74

Figure 1. Requirements Survey Results

Model/ Simulation Hierarchical Level	Requirements Survey DMSO Function Areas (Critical Environmental Factors)						
	Research and Development	Test and Evaluation	Analysis	Production and Logistics	Military Operations	Education and Training	Totals
Campaign			4 (2)		2 (1)	3 (2)	9 (5)
Mission	4 (3)		3 (3)	2 (2)	3 (1)	4 (3)	16 (12)
Many-on-Many / Few-on-Few	3 (2)	2 (2)	6 (3)		8 (5)	3 (2)	22 (14)
One-on-One	1 (1)	8 (6)	4 (3)		1 (1)	6 (6)	20 (17)
Engineering	5 (4)		2 (2)				7 (6)
Totals	13 (10)	10 (8)	19 (13)	2 (2)	14 (8)	16 (13)	74 (54)

Figure 2. Models and Simulations Categorized by DMSO Functional Area and Hierarchical Level

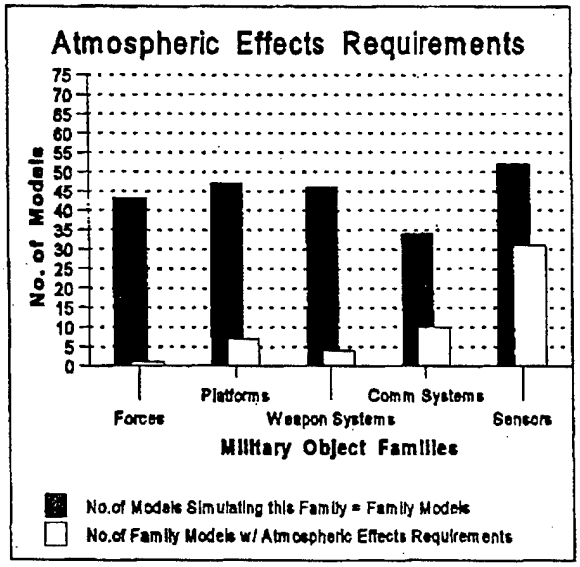

Figure 3. The number of models and simulations incorporating specific military object families and having atmospheric effects requirements for each military object family.

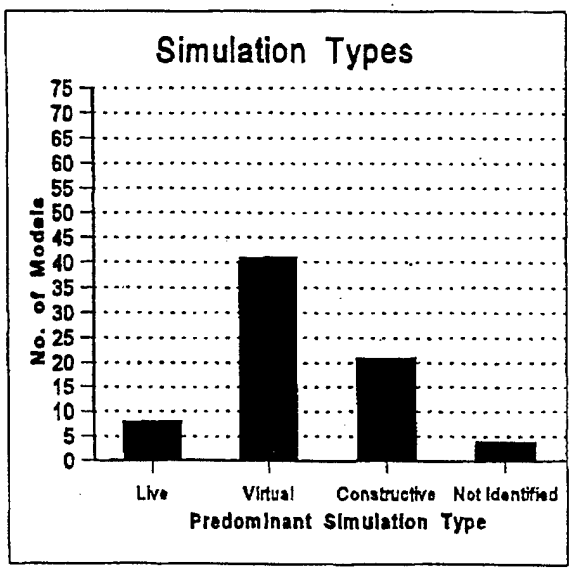

Figure 4. The number of models and simulations identified to be predominantly either live, virtual, or constructive.

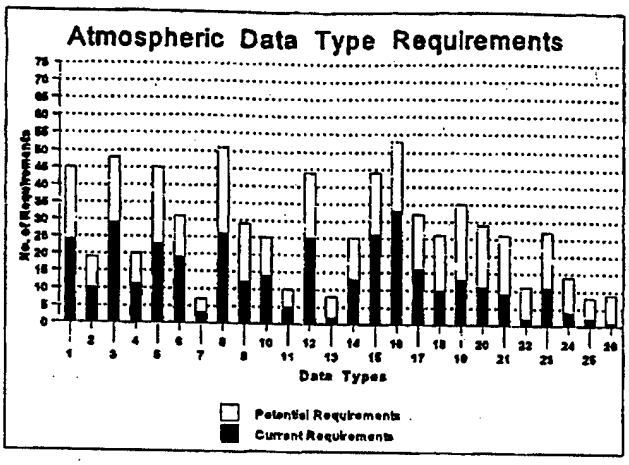

Figure 5. The number of requirements for each of the 26 atmospheric data types (see List).

Atmospheric Data Types

1. Aerosols
2. Atmospheric Electricity
3. Clouds
4. Dew Point
5. Fog
6. Humidity
7. Mixing Ratio
8. Precipitation
9. Refractivity
10. Sea Level Pressure
11. Static Stability
12. Temperature
13. Trace Gases
14. Transmissivity
15. Visibility
16. Wind
17. Wind Features (e.g., hurricanes)
18. Radiative Features (e.g., sky brightness)
19. Smoke
20. Chaff Dispersion
21. Combat-Generated Dust
22. Contrail Formation and Dispersion
23. Biological and Chemical Agent Dispersion
24. Nonnuclear Munitions Effects
25. Nuclear Detonation Effects
26. Ship Exhaust Tracks

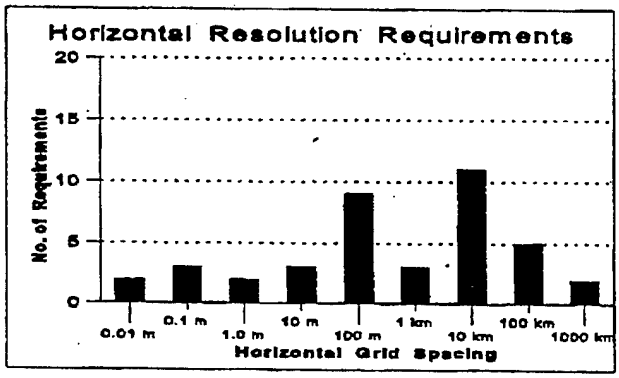

Figure 6. The number of horizontal resolution requirements for specific grid spacings.

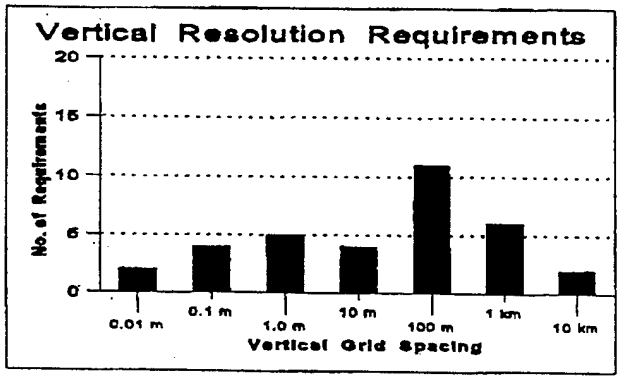

Figure 7. The number of vertical resolution requirements for specific grid spacings

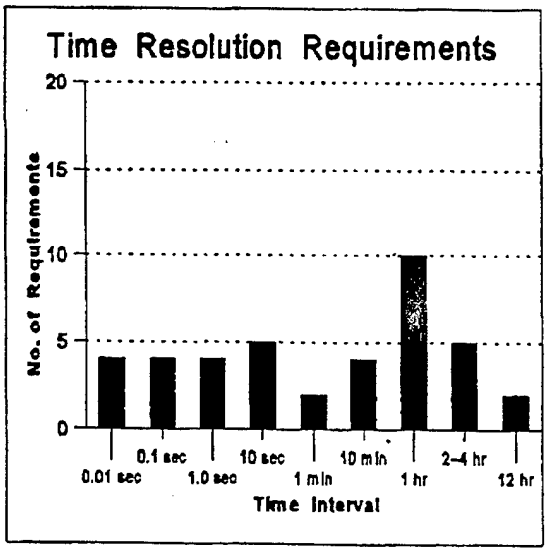

Figure 8. The number of time resolution requirements for specific time intervals.

US Military Service	Capabilities Survey Results			
	No. of Organizations Polled	No. of Organizations Responding	No. of Major M&S Efforts	No. of Questionnaires Completed
Army	6	5	31	31
Navy	26	14	60	58
Marine Corps	1	0	0	0
Air Force	7	3	65	63
Coast Guard	1	1	0	0
Totals	41	23	156	152

Figure 9: Capabilities Survey Results

Model or Simulation Hierarchical Level	DMSO Functional Areas						Totals
	Research and Development	Test and Evaluation	Analysis	Production and Logistics	Military Operations	Education and Training	
Campaign					1		1
Mission	2		12		5		19
Many-on-Many / Few-on-Few		1	10		1		12
1-on-1	33		21		25		79
Engineering	13	1	4		3		21
Not Indicated	6		4		8	2	20
Totals	54	2	51	0	43	2	152

Figure 10. Environmental Databases and Models Categorized by DMSO Functional Area and Hierarchical Level.

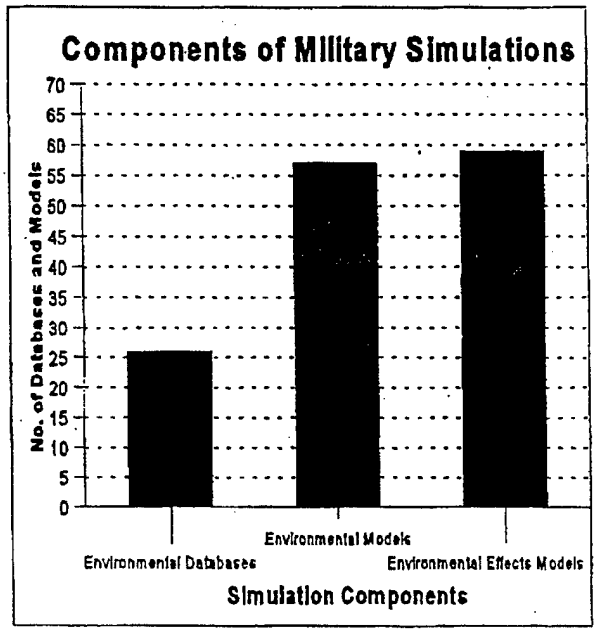

Figure 11. Surveyed environmental databases and models grouped as components of military simulations.

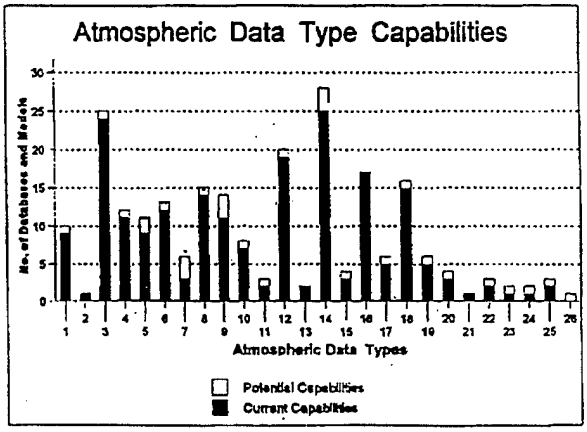

Figure 12. The number of environmental databases and models surveyed having a capability to provide a specific atmosphere data type. The 26 atmospheric data types are listed next to figure 5.

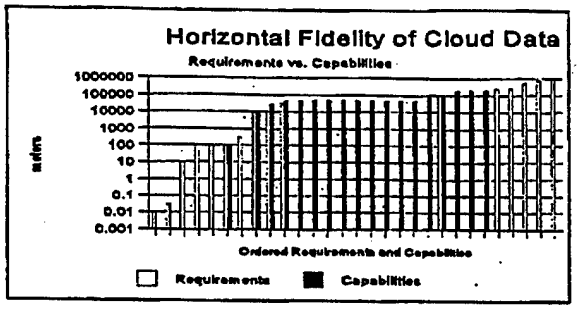

Figure 13. Comparison between environmental capabilities and M&S requirements for data on the horizontal structure of clouds.

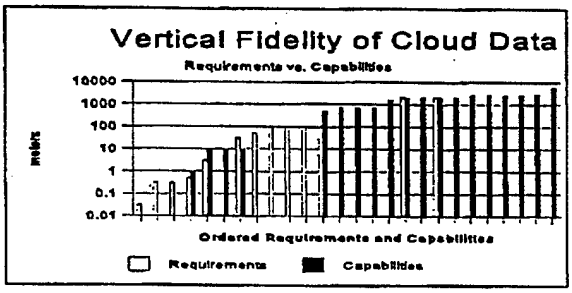

Figure 14. Comparison between environmental capabilities and M&S requirements for data on the vertical structure of clouds.

Primary Type of Atmospheric Data Required	Deficiency of Fidelity Capability (d) (D => Major Deficiency)		
	Horizontal	Vertical	Temporal
Aerosols	D	d	d
Clouds	d	d	
Fog	D	D	
Humidity	D	D	d
Precipitation	d		d
Temperature	d		
Visibility	D	D	d
Wind	d		d
Summary	4D/4d	3D/2d	5d

Figure 16. Overall Deficiencies of Current Environmental Models and Databases.

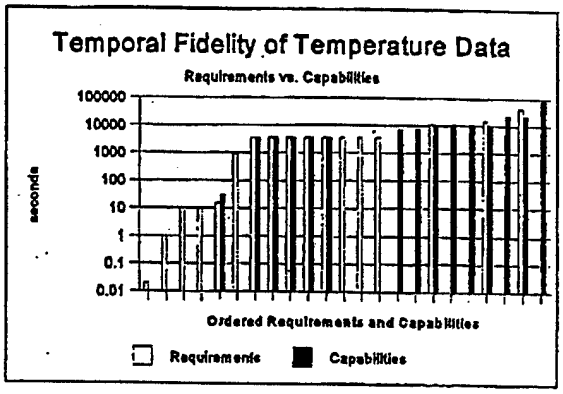

Figure 15. Comparison between environmental capabilities and M&S requirements for temporal data on temperature.

Primary Type of Atmospheric Data Required	Needed Fidelity of Capability		
	Horizontal	Vertical	Temporal
Aerosols	1000 m	100 m	
Clouds		100 m	
Fog	100 m	100 m	
Humidity	100 m	100 m	15 min
Precipitation	500 m		
Temperature	100 m		
Visibility	100 m; 10 km	100 m	10 s
Wind	100 m		5 s

Figure 17. Required New Environmental Models or Databases